

- V. "The Abductor and Adductor Fibres of the Recurrent Laryngeal Nerve." By J. S. RISIEN RUSSELL, M.B., M.R.C.P. Communicated by Professor V. HORSLEY, F.R.S. Received March 17, 1892.

(From the Pathological Laboratory of University College, London.)*

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INTRODUCTION.

While engaged in certain experimental investigations in connexion with the cervical nerve roots of the dog ('Roy. Soc. Proc.,' 1892), the ease with which I found one could separate, in a nerve root, the different bundles of nerve fibres which are concerned with one function from those concerned with another, or even a bundle of nerve fibres destined for the supply of one muscle from one destined for the supply of another, led me to suppose that by exercising sufficient care, it might be possible to separate, in the same way, the abductor from the adductor fibres in the recurrent laryngeal nerve. It is a matter of clinical and pathological experience (Semon, Rosenbach) that in organic and progressive affections of this nerve the abductor fibres are prone to succumb before the adductors; but why this should be so is not at all clear. In like manner, in the well-known experiments of Gad and B. Fränkel† on freezing the nerve, the abductor fibres give way before the adductors do. Jeanselme and Lermoyez,‡ by electrical excitation of the laryngeal muscles of human

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† 'Centralblatt für Physiologie,' May 11, 1889.

‡ 'Arch. de Physiol. normale et pathol.,' No. 6, 1885.

subjects who died of cholera, found that the crico-arytenoideus posticus muscles were the first to lose their excitability after death. This observation has been abundantly confirmed by Horsley and Semon* for all classes of animals. On the other hand, ether, reaching the laryngeal muscles through the circulation, puts the adductors into abeyance before the abductors, so that, while excitation of the recurrent nerve of an animal not very deeply under its influence results in adduction of the corresponding vocal cord, similar excitation of the nerve when the animal is profoundly under the influence of the anæsthetic results in abduction of the cord.† It seemed, therefore, not unlikely that, if the fibres dominating over the one function could be successfully separated from those dominating over the other, some fresh light might be thrown on this subject.

It is interesting to find that Dr. Felix Semon,‡ in a paper written so long ago as 1881, asked the following question with regard to the fibres of the recurrent laryngeal nerve: "Are we to suppose that, though the nerve is apparently homogeneous, it consists in reality of a bundle of strictly differentiated fibres, bound together simply by a common nerve sheath, and actually differentiated throughout their peripheral course; in fact, having ganglionic centres of their own?" Dr. Semon then goes on to show that the pathological facts strongly support the probability of the truth of this hypothesis.§

Morell Mackenzie,|| in his text-book published the year before Semon raised this question, suggested that possibly the abductor filaments were more superficially situated than the adductor fibres, and that this, if true, would account for the proneness of the abductors to succumb before the adductors in affections, especially compression by tumours, of the nerve. There is, however, no ground for this hypothesis.

Since then, the general question of the proclivity of the abductor fibres has been the subject of great controversy, and has been debated both from a clinical and pathological standpoint,¶ but, so far as I am aware, very few attempts have been made to determine

* 'British Medical Journal,' Aug. 28 and Sept. 4, 1886.

† Hooper, 'Trans. of the Amer. Laryngol. Assoc.,' vol. 7; Horsley and Semon, 'British Medical Journal,' Sept. 4 and 11, 1886.

‡ Semon, 'Arch. of Laryngology,' 1881, vol. 2, p. 200.

§ Dr. Semon's views have been amply confirmed by direct experiments on the cortical and bulbar centres for the laryngeal muscles. See history of the subject in paper by Semon and Horsley, 'Phil. Trans.,' 1890.

|| Mackenzie, 'A Manual of Diseases of the Throat and Nose,' 1880, vol. 1, p. 440.

¶ For a full history of this, see Semon's contribution to the 'Virchow-Festschrift'; "Die Entwicklung der Lehre von den motorischen Kehlkopfaffektionen seit der Einführung des Laryngoscops," 1891.

the arrangement of the fibres in the trunk of the recurrent laryngeal nerve, either by anatomical observation or direct experimental investigation.

HISTORICAL ACCOUNT OF PREVIOUS EXPERIMENTAL RESEARCHES.

Hooper,* wishing to decide, by experimental investigation, whether it is the abductor or the adductor fibres that are really the more prone to succumb in affection of the recurrent laryngeal nerve, passed a thread through the middle of one recurrent nerve, and left it *in situ* in the hope that it would act as a foreign body and excite inflammation of the nerve. At the end of a week, on inspecting the larynx, the vocal cord on the side corresponding to the injured nerve was observed not to come up to the middle line with the same "snap" on expiration as did the cord of the opposite side.

The nerve was found imbedded in a mass of inflammatory tissue, and electrical stimulation of its trunk below this point resulted in abduction of the corresponding vocal cord. When a strong current was used, stimulation of the nerve resulted in abduction of the vocal cord of the same side, and adduction of that of the opposite side. The opposite uninjured nerve was next divided, and adduction of the vocal cord on this side followed stimulation of its peripheral end. Division of the injured nerve below the point at which the thread had been inserted, and stimulation of its peripheral end, resulted in distinct outward rotation of the arytenoid cartilage of that side and an approximation of both arytenoid cartilages at the same time. All attempts to verify these results have failed, so that the experiment stands alone. Proneness of the adductors to suffer before the abductors is what this experiment seemed to point to, but the observer was unable to lay very great stress on this single experiment, positive as it seemed.

The possibility of direct injury to the adductor fibres during the process of inserting the thread into the nerve does not seem to have occurred to this observer, a possibility which is more than likely. Further, it is quite evident that the effects he obtained on the opposite cord, by stimulating the injured nerve, were due to diffusion of the electrical current to the nerve of the other side by diffusion to the vagal trunk, and so reflexly to the opposite nerve.

Onodi† exposed the muscles of the larynx in dogs, and found that at the point where the recurrent laryngeal nerve crosses the crico-arytenoideus lateralis muscle it splits into three bundles, the first of which supplies the crico-arytenoideus posticus, the second the arytenoideus transversus and crico-arytenoideus lateralis, and the third

* Hooper, 'New York Med. Journ.,' July 4, 1885.

† Onodi, 'Berliner Klin. Wochenschr.,' 1889, No. 18.

the thyro-arytenoideus externus. He passed a ligature round each branch, divided all three branches, and then stimulated each separately by an electrical current, and noted the movements of the vocal cords. The communication is an exceedingly brief one; but the observer promised to publish a full account of his experiments later. As far as I am aware, no such publication has appeared up to the present.

These observations can scarcely be said to have thrown much fresh light on the question at issue, as it is only natural to suppose that this nerve, in common with all other motor nerves, should so near its peripheral termination divide into several branches, and that stimulation of each branch of the nerve should evoke contraction of the muscle which it supplies, and thus bring about the particular movement of the vocal cord over which the muscle presides. But this does not at all decide the all-important question as to whether the nerve fibres presiding over the different functions have a separate course throughout the entire length of the nerve trunk or not.

Dionisio* performed tracheotomy, and then inserted a laryngeal "dynamometer" between the cords. This consisted of a small india-rubber ball, which communicated by means of a tube with a mercurial manometer. The height of the mercurial column during inspiration and expiration was then noted during the natural movements of the vocal cords, its position during expiration being of course higher than during inspiration. The recurrent laryngeal nerve was exposed and stimulated with an electrical current sufficiently strong to produce moderate adduction of the corresponding vocal cord, during which the mercurial column rose. When excitation was discontinued it fell again, and oscillated between the two former points. Circular pressure was then applied to the nerve, commencing with 5 grammes, and going up to 350 grammes, by gradual stages; pressure being kept up for $2\frac{1}{2}$ minutes at each stage. It was found that on stimulating the nerve after each stage there was a gradual diminution in its power of conduction, until stimulation on the proximal side of the point of pressure no longer gave any response, while stimulation on the distal side resulted in a rise of the pressure, but not nearly so great as formerly. There was a gradual fall of pressure, the inspiratory and expiratory preserving about the same ratio they bore to each other before the pressure was commenced.

OPERATIVE PROCEDURE.

Dogs were without exception the animals used in these experiments, and in every case ether narcosis was produced and continued throughout the whole course of the experiment, at the end of which the animal was always killed by an overdose of the narcotic, except in

* Dionisio, 'Arch. Italiani di Laringol.,' January, 1892, p. 1.

the case of those instances in which it was necessary to allow the animals to live for three weeks, for the study of the degenerations which followed section of certain parts of the nerve. In the latter case the operation, which was always of the most trivial character, was performed under strict antiseptic precautions, and the small wound afterwards treated antiseptically. In every case the small wound healed by immediate union. The animals were narcotised in these, as in the other, experiments, and at the end of three weeks death was produced by means of an overdose of chloroform.

Tracheotomy was performed in every instance (except when the animal was to be allowed to live after the operation), a glass cannula being inserted into the trachea. A short rubber tube connected the free end of the cannula with a glass funnel, through which the anæsthetic was administered during the remainder of the experiment. The trachea was then completely divided transversely above the point at which the tube had been inserted. A window was cut from the upper portion of the divided trachea and raised gently, so as to give a full view of the larynx, as seen from below, without producing the least traction on the parts, which might disturb their normal play of movement.*

One or other of the recurrent laryngeal nerves was next exposed, separated from the loose connective tissue which surrounds it, and a ligature passed round the trunk of the nerve at the lower part of the neck. The nerve was then divided on the proximal (*i.e.*, bulbar) side of the ligature, and its peripheral end was separated into its component bundles of nerve fibres, round each of which a ligature was passed and secured.

In the operation for the production of control results by the degeneration method, the nerve, after being exposed and separated from the surrounding connective tissue, was placed *in situ* upon a piece of cork, in order to steady it, and one bundle of nerve fibres being carefully separated from the others which compose the nerve, a few millimetres of this bundle were excised. These operations were performed under strict antiseptic precautions, the wounds closed by continuous aseptic silk sutures, and afterwards dressed antiseptically, healing by first intention, tracheotomy not having been performed.

* In observations of this kind it is absolutely essential to view the larynx without traction on the attachments of the cords, since in the dog and the cat traction on the larynx, whether by a ligature directly attached to it, or indirectly by pulling forward the tongue, may most easily produce the appearance of either paralysis or spasm of one vocal cord where no such condition exists in reality.

DIVISION OF SUBJECT AND ANALYSIS OF RESULTS.

A. *Division of Subject.*

The first part of the following research consists in the separation and isolation of the different bundles of nerve fibres of which the nerve trunk is composed, electrical excitation of each separate bundle, and observation of the effects produced on the vocal cords by such excitation.

Exposure of the different bundles of nerve fibres under exactly similar circumstances to the drying influence of the external air, with observation of the relative duration of vitality possessed by the different bundles, forms the second part of the investigation.

Other methods were next instituted to control the results of the foregoing, and the first of these, constituting the third part of this work, consisted in tracing by *post-mortem* dissections each bundle of nerve fibres separated in the nerve trunk to its termination in the mucous membrane or in a muscle of the larynx.

The next control method consisted in exposing the muscles of the larynx immediately after death, and direct observation of them during excitation of the separate bundles of nerve fibres, this being controlled by occasional excitation of individual muscles themselves. This forms the fourth part of the investigation. The fifth or last part of the research served as a third control method, and consisted in observations of the muscular degenerations which followed division of one or other bundle of nerve fibres in the nerve trunk, three weeks after such division.

B. *Analysis of Results.*

Section 1. Separation and Excitation of the Individual Bundles of which the Nerve is composed.—The separation was brought about by means of an exceedingly delicate thin-bladed knife. The divisions between the different bundles of fibres could usually be seen by the naked eye, and further guides were the minute capillary twigs which usually course on the surface of the nerve along these lines of division. When no such guides could be seen by the unaided eye, a lens was used to assist in their recognition. Great care was taken to preserve the vitality of the nerve fibres by constantly bathing them with warm normal saline solution. Each bundle was in turn raised into the air, and stimulated by means of fine platinum electrodes attached to the secondary coil of a du Bois-Reymond's inductorium, supplied by a bichromate cell. The same strength of current was used for all the bundles of nerve fibres in any given experiment, and was on an average 5000 to 7000 on Kronecker's inductorium scale; and the rate of interruption was 100 per second. The results in twelve dogs

showed that excitation of certain bundles produced no effect on the vocal cord, while excitation of others produced abduction or adduction of the vocal cord on the same side, according to the bundle of fibres stimulated; and, as far as could be ascertained, those fibres excitation of which produced abduction of the cord were situated internally to those which produced adduction, *i.e.*, the former are situated on the side of the nerve next to the trachea. But of this point it is difficult to be absolutely certain, as the difficulties of preserving the nerve in its normal position during the investigation are very great.

Section 2. Relative Vitality of the respective Bundles.—It was found that if the bundles of nerve fibres were separated, as has been already explained, and the abductor and adductor bundles of fibres thus isolated placed upon a piece of cork, and left exposed to the air of the room under exactly similar circumstances, the abductor fibres ceased to conduct impulses in response to electrical excitation long before there was the slightest sign of similar failure on the part of the adductors. The same strength of current and the same number of interruptions per second were employed in each case, with the result that the abductor fibres ceased to conduct impulses in about twenty to thirty minutes, on an average, after transverse section of the nerve and separation of its component bundles; while the adductor fibres would continue to conduct impulses well for three hours and more.*

That this death of the abductor fibres did not take place throughout the whole length of the nerve at the same time is proved by the fact that when the portion under observation ceased to conduct impulses, an effect could be often produced by stimulating some portion of the bundle situated nearer the peripheral end of the nerve, until at last even stimulation of the nerve ends in the muscle failed to produce any effect. The adductors meanwhile acted well to the original strength of stimulus, even when applied to the original seat of separation of the bundles. As is well known, if all the fibres of the recurrent laryngeal nerve be stimulated simultaneously in the adult dog, adduction of the vocal cord results; while the same procedure in the young dog results in abduction of the vocal cord. (See all previous observers from Legallois to Semon and Horsley.) In such young animals, even after separation of the different bundles of nerve fibres in the trunk of the nerve from each other to the extent of an inch to an inch and a-half, it is at first impossible to get any other effect than abduction of the corresponding vocal cord. But there comes a time when stimulation of one of the separated bundles results in abduction, while stimulation of another results in adduction. Still later

* The experiment was never continued longer than a little over three hours, as there seemed no necessity for it.

the abductor bundle ceases to produce this effect when stimulated with a moderate strength of current, and when a very strong current is used adduction of the vocal cord follows, as in the case of stimulation of the other bundle of nerve fibres. The explanation of these phenomena seems to be that in the young dog the abductor fibres are more excitable than the adductors, so that a strength of current short of that necessary to evoke action of the adductor muscles diffuses to the abductor fibres, which, being more excitable, cause abduction of the vocal cord; but that, as in the adult animal, the tendency to death of the abductor fibres is more marked than that of the adductors, so that there comes a time in the young animal when the abductor fibres have so far lost their excitability that stimulation of the adductor bundle with a current strong enough to evoke contraction of the adductor muscles, though it still diffuses to the abductor fibres, is no longer capable of exciting them, and in the end the abductor fibres lose completely their excitability, while the adductors, though relatively less excitable in the beginning, preserve their excitability, even in this case, longer than the abductors, which on their part preserve it much longer than in the adult animal.

Section 3. (Control) Tracing the respective Bundles to their Peripheral Terminations by Dissection.—Having ascertained by electrical excitation the functions subserved by the different bundles of nerve fibres in the nerve trunk, these bundles were traced *post mortem* by careful dissection to their peripheral terminations. All the bundles of nerve fibres were thus dealt with, but the present research does not make it necessary for a description to be given of any but the motor fibres. From several such dissections, taken together with the facts ascertained during the excitation experiments, it seemed almost certain that the abductor bundle of nerve fibres is situated on the inner side of the nerve, *i.e.*, next to the trachea, while the adductor bundle is situated on the outer side of the nerve. The abductor bundle may be traced to the crico-arytenoideus posticus muscle on the same side, and to it alone, none of the fibres to the adductors being contained in this bundle; while the adductor bundle supplies branches to all the adductor muscles on the same side, and to the arytenoideus.

Section 4. (Control) Direct Observation of the Abductor and Adductor Muscles in Action after Dissection.—In six dogs the nerve was exposed at the lower part of the neck, and the different bundles of fibres separated. The nerve fibres were carefully preserved by being covered with a piece of cotton wool saturated with warm normal saline solution. The animal under observation was then killed by an overdose of chloroform, the larynx quickly excised, and its muscles exposed by dissection.

By this method, on excitation of the nerve fibres not only could the movements of the vocal cords be seen, but also the contraction of the

muscles directly engaged in bringing about the movement of abduction or adduction, as the case might be. These observations showed that so perfectly could the nerve fibres concerned with the one function be separated from those concerned with the other, that stimulation of the one set evoked contraction of the abductor muscle alone, while stimulation of the other set evoked contraction of the adductor muscles alone.

Section 5. (Control) Degeneration Method.—The difficulties which attended this group of experiments were very great.

An attempt was made to separate one bundle of nerve fibres from the others, and to excise a few millimetres of it without injuring the other bundles contained in the nerve trunk, and, of course, without severing the whole nerve trunk. As can be easily understood, the ease with which damage can be done to so delicate a nerve is very great, and in the absence of any means of fixing the nerve (such as was afforded by the ligature in the excitation experiments) without producing damage to any but the bundle of fibres that were to be eliminated, the nerve trunk rolled about so freely that the task was attended by endless difficulties. It is, therefore, scarcely surprising that, out of seven experiments, the results were unsatisfactory in three instances. But those that were successful yielded such striking results that, in view of the great difficulties attending them, further multiplication of these experiments has been considered unnecessary. In one instance, the adductor fibres in the nerve trunk were successfully separated, and a few millimetres excised. As in all these experiments, the wound healed by primary union; and when the dog was killed, three weeks after operation, the autopsy revealed the following:—The adductor muscles on the side of the damaged nerve were atrophied and degenerated, while the abductor muscle of the same side was normal, as were naturally all the muscles of the opposite side of the larynx.

In two instances the abductor fibres were successfully divided without injury to the adductor fibres. During life in one case, there were feeble attempts at abduction during vigorous inspiration, and in the other there were not the slightest signs of abduction. In both cases the autopsy revealed atrophy and degeneration of the crico-arytenoideus posticus on the side corresponding to that of the injured nerve, while the adductor muscles of the same side and all the muscles of the opposite side of the larynx were normal. In all these three cases direct electrical excitation of the muscles confirmed the conclusions which had already been come to by observing their loss of function and degenerate appearance. In the fourth case, as was supposed at the time of the operation, owing to their position, the bundle of fibres divided was evidently not one of those supplying the muscles of the larynx. Three weeks after the operation the vocal

cord on that side performed its excursions perfectly normally, as did that of the opposite side. Separation of the abductor and adductor fibres was then effected in the remainder of the nerve trunk, and excitation of these bundles evoked their respective movements of the vocal cord on the same side. Finally, on post-mortem examination in this case, none of the muscles on either side of the larynx were found atrophied or degenerated. It consequently served as a gratifying control of the other degeneration experiments.

SUMMARY AND CONCLUSIONS.

The results of these experiments show clearly :—

1. That the abductor and adductor fibres in the recurrent laryngeal nerve are collected into several bundles, the one distinct from the other, and each preserving an independent course throughout the nerve trunk to its termination in the muscle or muscles which it supplies with motor innervation, a condition of things the possibility of which was suggested by Dr. Semon more than ten years ago, from the evidence of pathological facts.
2. That while in the adult animal simultaneous excitation of all the nerve fibres in the recurrent laryngeal nerve results in adduction of the vocal cord on the same side, abduction is the effect produced in a young animal by an exactly similar procedure.
3. That when the abductor and adductor fibres are exposed to the drying influence of the air under exactly similar circumstances, the abductors lose their power of conducting electrical impulses very much more rapidly than the adductors, in other words, they are more prone to succumb than are the adductors, a fact which has for long been recognised and insisted on by Dr. Semon as being the case in the human subject, and in support of the truth of which that observer has adduced so many powerful arguments.
4. That, even in the young dog, the abductor nerve fibres, though preserving their vitality much longer than in the case of the adult animal, nevertheless in the end succumb before the adductor fibres.
5. That this death commences at the point of section of the nerve, and proceeds gradually to its peripheral termination, and does not take place in the whole length of the nerve simultaneously.
6. That it is possible to trace anatomically the abductor and adductor fibres throughout the whole length of the recurrent laryngeal nerve to their termination in the one or other group of laryngeal muscles, and that these fibres appear to bear a fixed relationship to each other throughout their course, the abductors being situated on the inner side of the nerve or that next to the trachea, while the adductors are on the outer side.
7. That it is possible to so accurately separate these two sets of

fibres in the nerve trunk that excitation of either of them evokes contraction of the abductor or adductor muscles, as the case may be, without evoking any contraction whatever in the muscle or muscles of opposite function.

8. That the bundle of nerve fibres concerned with one function may be divided without injury to that concerned with the opposite function, and that such division is followed by atrophy and degeneration of the muscles related to that function without any such changes being detectable in the muscles related to the opposite function.

Further, it was clear that the theory advanced by Mackenzie, and which has since found favour with many, viz., that possibly the reason why the abductor fibres succumb before the adductor in affections of the nerve is because they are more superficially and circumferentially arranged, while the adductor fibres are situated deep in the substance of the nerve, is shown by these experiments to be entirely erroneous.

One point which is difficult to explain is why there should be so marked a difference between the recurrent laryngeal nerve of a young and that of an adult dog, as regards the respective predominance of abductor or adductor representation in the trunk of the nerve. Possibly the reason why the abductor influence is in the ascendancy in the young dog is because the power of phonation is still imperfectly developed, and with it both the muscle and nerve fibres subserving this function are also imperfectly developed, while the function of respiration is from the beginning fully developed, and with it the muscle and nerve fibres connected with that function. That the reverse should be the case in the adult animal may well be due to the fact that phonation is perfectly developed, while respiration has become so automatic that very feeble stimuli are necessary to keep it going.

My sincere thanks are due to Professor Victor Horsley for allowing me to carry out this research in the Pathological Laboratory of University College, London, and for being so good as to verify the results which I obtained from time to time.

I wish also to express my thanks to Dr. Felix Semon for having very kindly given me access to his valuable collection of literature on the subject, and facilitating the work of writing this paper.